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PARTNERSHIP FOR THE ADVANCEMENT OF INFRASTRUCTURE AND ITS RENEWAL THROUGH INNOVATIVE TECHNOLOGIES TRANSPORTATION COMPONENT (PAIR-T) WHITE PAPER

U.S. DEPARTMENT OF COMMERCE
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EXECUTIVE SUMMARY

The Partnership for the Advancement of Infrastructure and its Renewal (PAIR) is conceived as an umbrella partnership of existing and future government, private sector, and academic programs to develop the innovative products and practices needed to revitalize and advance the nation's physical infrastructure. Our national "infrastructure" comprises the civil and military transport, water, sewerage, waste management, electrical power, gas and liquid fuels, and communications systems. The Partnership will create a constituency—a national partnership based **on the recognition that all of us in the public and private sectors are stakeholders and users of the infrastructure** and it is only collectively that we can make an impact on revitalizing this critical national asset through innovation. This paper sets forth the vision, objectives, participants, collaboration areas, and funding considerations for the transportation component of PAIR, which is called "PAIR-T." The purpose of PAIR-T is to create an environment that fosters an **unprecedented level of collaboration and synergy** on research and development (R&D), demonstration, testing, evaluation, and, especially, technology transfer to state and local institutions, the true custodians of the nation's civil transport infrastructure.

The ultimate goal of PAIR-T is to **accelerate the comprehensive renewal *and advancement*** of the aging civil transport infrastructure, moving toward the realization of a truly "sustainable" system. Theoretically, this ultimate sustainable system will be so maintenance-free, durable, and efficient that fewer and fewer human, economic, and environmental resources will be required to operate and maintain it. In the near term at least, the reality is likely to be somewhat less grand. More likely the Partnership may mean that more resources are freed so that a greater part of the transport infrastructure that is wanting may be rebuilt or replaced at a faster pace than would otherwise be possible.

PAIR-T planners recognize that many of the programs necessary for a broad-based constituency supporting infrastructure revitalization are already in place. The Partnership will build on these programs, creating a climate that aggressively fosters public-private sector collaboration and effectively leverages limited national resources. Thus PAIR-T will have two critical roles. First, it will serve as a "bully-pulpit," drawing attention to the huge unmet national infrastructure needs and disseminating information about relevant current or planned research, deployment, and revitalization programs. The Partnership will work to expand the effectiveness of these programs, encouraging greater collaboration and leveraging of funds between and among public and private sector institutions. Such an effort should result in additional funds becoming available for infrastructure revitalization. Second, the Partnership will help to coordinate and facilitate the development of new programs focused on transportation infrastructure R&D, demonstration, testing, evaluation, and technology transfer. While PAIR-T will not assume management responsibility for each of these programs, the Partnership will be a vehicle for their planning and coordination.

PAIR-T stakeholders comprise *all users* of the nation's transport infrastructure. PAIR-T strategists have estimated that an **initial increase of $10 million annually in private and public sector R&D** for improved products and practices for infrastructure renewal is needed. This commitment should encourage and nurture real collaboration among the stakeholders in the civil transport infrastructure. As enthusiasm for PAIR-T grows and the partnership activities begin to bear fruit, additional private and public R&D should grow to $60 million or more per year. This level of financing over 10 years is but one-tenth of one percent of the estimated $600+ billion required to renew our transportation infrastructure. It is *in addition* to some of the important revitalization programs already in place. The forthcoming reauthorization of transportation legislation (Intermodal Surface Transportation Efficiency Act [ISTEA]) might serve as a major catalyst for the PAIR-T initiative.

The Partnership estimates the PAIR-T return on investment in infrastructure renewal over the next 10 years will be close to 300 percent. The ultimate **measures of the success** of PAIR-T, however, will be: (1) the daily beneficial effects it has on the traveling public; (2) the extent to which work performed under the PAIR-T umbrella conserves the resources of the city, state, and local governments responsible for improving and maintaining the infrastructure; (3) the degree to which partnerships bring together discrete and distinct private and public sector programs to achieve a common end; and (4) the ability to educate taxpayers about the national security, impact of global change, environmental stewardship, and performance benefits generated through innovation in infrastructure renewal.

The PAIR-T initiative is ambitious. Historical under-investment in our nation's civil transport infrastructure has led to massive decay and accelerated obsolescence. As indicated above, a cursory survey of readily available statistics suggests that comprehensive and effective renewal of the nation's basic surface transport infrastructure could come with a price tag of more than $600 billion. Liability concerns and a highly fragmented infrastructure "industry" combine to discourage innovation. The Partnership will bring together all stakeholders to support a movement focused on infrastructure revitalization. The Partnership will build on, and make more effective use of current and planned public and private programs to stimulate surface transport infrastructure revitalization

PAIR-T would mark virtually the first time since the development of the national Interstate Highway System that resources from *every* sector of the American economy would be brought together to solve a problem of monumental proportions. Once established, PAIR-T will promote the accelerated use of advanced materials and technologies towards creating a 21st century infrastructure.

The PAIR-T initiative will be carried out in multiple phases: near-term (1998-2002), mid-term (2003-2008), and long-term (> 2008). An incremental approach to program implementation is based on the conviction that the initiative is so broad in scope and constituency that flexibility must be built in to accommodate changing priorities and foster realistic expectations.

PAIR-T is intended to build on and leverage programs developed by a variety of federal agencies, particularly the Department of Transportation (DOT), as well as the Transportation Research Board (TRB), the American Association of State Highway and Transportation Officials (AASHTO), the Rebuild America Coalition, and many other organizations whose participation and support are essential. **PAIR-T is envisioned as a loosely coordinated partnership between industry and government rather than a pooling of resources under one management entity**. The Civil Engineering Research Foundation (CERF), the non-profit research affiliate of the American Society of Civil Engineers (ASCE), will serve as Secretariat.

THE PARTNERSHIP VISION

The Partnership for the Advancement of Infrastructure and its Renewal (PAIR) is conceived as an umbrella under which existing and future government, private sector, and academic programs will be jointly guided to develop the innovative products and practices needed to revitalize and advance the nation's physical infrastructure. Our national "infrastructure" comprises the transport, water, sewerage, waste management, electrical power, gas and liquid fuels, and communications systems, and everyone has a stake in its performance. While innovation abounds in many sectors of the nation's economy, in infrastructure, new technologies are not keeping pace with the demands of business markets and public priorities.

Every business depends on the nation's infrastructure. Infrastructure influences fundamentally a firm's access to markets, costs of doing business, and productivity of its workforce. Unless we can accelerate the pace of infrastructure innovation, America's 21st century businesses will be shackled by the high costs of an ineffective, decayed, inadequate, and obsolete infrastructure. Further, we will miss global market opportunities for developing new ideas, science, and technology to improve infrastructure.

The public depends on infrastructure as well. Infrastructure fundamentally influences our access to jobs and recreation, our personal health and safety, and how we function as a society. Unless we can accelerate the pace of infrastructure innovation, America's 21st century communities will suffer increasing congested systems, unreliable services, escalating costs, and deteriorating physical environment.

PAIR-T, the transportation component of PAIR, is **conceived as a critical part of the umbrella partnership** of existing government, private sector, and academic programs concerned with all aspects of the national infrastructure. The purpose of the partnership is to create an environment that fosters an **unprecedented level of collaboration and synergy** on research and development (R&D), demonstration, testing, evaluation, and technology transfer to state and local institutions, the true custodians of the nation's civil transport infrastructure. The ultimate goal of PAIR-T is to **accelerate the comprehensive renewal *and advancement*** of the aging civil transport infrastructure, moving eventually toward the installation of a "sustainable" system. PAIR-T may mean that more resources are freed so that a greater part of the transport infrastructure that is wanting may be rebuilt or replaced at a faster pace than would otherwise be possible.

PAIR-T would be not only responsive to transportation issues, it would address concerns of global import such as climate change from the emissions of greenhouse gases. An infrastructure that is more durable and efficient will consume fewer fossil fuels in maintenance, repair, and operation than existing transport systems. Climate change prevention is a highly visible issue at all levels of government.

PAIR-T will be a comprehensive integration of the full spectrum of innovations the scientific and engineering communities can bring to bear on the problem. The widespread use of high-performance construction materials in applications ranging from more durable bridges to easier-to-maintain port facilities is just beginning. State-of-the-art construction practices are anything but routine for all but a handful of construction companies. Innovative technologies ranging from intelligent transportation systems (ITS) to real-time remote sensing networks will be woven together into a durable, high-performance, and coherently-patterned fabric that is laid across the American landscape. The nation's urban areas will receive the highest-priority in PAIR-T, particularly urban intermodal sites. PAIR-T efforts will be directed to the evaluation and deployment of existing, but underused, state-of-the-art technologies and R&D of entirely novel advanced infrastructure concepts for the 21st century. The bulk of PAIR-T resources will be directed toward accelerating the deployment of innovative and enhanced construction materials and technology, products, and systems.

ECONOMIC AND TECHNOLOGICAL IMPACTS

Resource economists and public works planners have long known the importance of infrastructure to economic prosperity. The transport infrastructure system, however, is taken for granted by most users. In addition, innovations in infrastructure have largely escaped the attention of the general public.

Infrastructure and Obsolescence

When the Erie Canal was opened for commerce, the cost of shipping wheat between New York City and Buffalo fell from $100/ton to $10/ton, providing dramatic evidence of the benefits of infrastructure innovation and improvement. But how does the quality of infrastructure affect urban and regional economies today? Obsolescence is as great an impediment to healthy economic growth as decay. If the Erie Canal were perfectly durable (i.e., in like-new condition) it would still be too narrow and too slow an inland waterway to be effective in the 1990s.

Changes in modal preferences based on cost are having a fundamental defining effect on obsolescence. Micro-economic decisions have macro-economic impacts. Commercial and industrial relocation data over the last decade show that the availability of rail services, expressways, and utilities—in that order—are the three leading factors in final site selection. However, four important factors, one historical and three relatively recent, have combined to reaffirm the role of obsolescence in retarding economic growth. First, the advent of the Interstate Highway System caused freight and passenger rail service to decline rapidly. Second, the booming growth of suburban office, commercial and industrial parks that necessarily rely on truck access have increased the demand for high-quality highway and roadway networks. Third, the proliferation of high-technology, non-durable goods (i.e., those with a high imbedded value-to-weight ratio) require access to sophisticated air transport and trucking services, rather than rail services. Fourth, the emergence over the last decade of "transport brokers" and "just-in-time" inventory replenishment and product delivery practices have given frequent truck trips and truck docking facilities greater importance as determinants in site selection. The rise of trucking and sophisticated airfreight in today's domestic economic growth should have been anticipated by infrastructure planners decades ago.

The State of the Art

The 21st century is already at hand. Advances that were unthinkable even a decade ago are on the near horizon. For example, the use of high-performance materials and technologies promise to revolutionize the way we build, maintain, and operate the nation's built structures. A few examples of recent advances are mentioned in the following paragraphs.

Faster and cheaper installation methods for constructed facilities promise to offer tangible and visible benefit to **all** users of the nation's transport infrastructure. The huge loss of labor productivity caused by traffic delays, detours, and downtime associated with bridge and highway repair will drop dramatically as engineers take advantage of the enormous potential of a variety of advanced construction materials and practices. For example, the fiber-reinforced polymer (FRP) composite community is refining a new generation of vehicular bridges using modular construction techniques. These bridges are pre-fabricated off site, which strengthens quality control. The modular bridge units may be transported over the road and installed in one eight-hour day. Similarly, advances in high-performance concrete indicate that for many types of designs, most of the downtime for repairs of bridges, tunnel and pavement overlays could be virtually eliminated by using high-performance concrete that gains a strength of 48 MPa within an hour of placement. Comparable advances in durability, safety and overall performance could be realized in just the next few years using the impressive capabilities of these advanced construction materials.

Similarly, advances in aluminum offer an opportunity for a simple and quick retrofit to extend existing bridge life, as well as offering upgrades in load-carrying capacity. Automated steel erection methodologies promise to reduce construction time greatly, while improved ductility and toughness of the steel will be a critical asset in structures constructed in seismic sensitive areas. Hundreds of thousands of bridges, water towers, and other public structures are coated with lead-containing paint and other contaminants. High-performance coating systems, employing robotics and remote control sensing will accelerate such operations as paint removal, waste separation, abrasive recycling, and dust control.

The transportation community is developing technologies to obtain real-time, non-intrusive information on bridge and highway condition, including water flow rates, scouring effects, support creep, icing conditions, fatigue, cracking, and corrosion damage. These conditions can be tracked and analyzed remotely, without

any need for on-site, in-situ inspection and without regard to weather conditions. The monitoring devices under development will also track and analyze much of hazardous materials transport on highways. A combination of microwave, optical, and laser data gathering systems will be used to transmit data.

So-called "smart" materials have already become commonplace in such areas as shape memory metal alloy (SMA) eyeglasses, piezoceramic copier devices, viscoelastic brake pads, and active polymeric implants. In the construction community, engineers are beginning to use a variety of self-repairing materials. SMAs may also be used to repair and retrofit bridges, docks, and highways, among other transport elements. SMAs can restore a structural component to its original shape, stiffness or orientation, the restoration being a function of the metallic memory selected and incorporated in the alloy during its formation.

The ITS field is similarly compelling in its potential. Utilizing satellite, radar, and other computerized communications equipment, the potential improvements in safety, efficiency, accessibility, and comfort are startling. On board radar systems may permit vehicles to travel closer together. Global positioning satellite navigation systems allow pinpoint location to within a meter or less. On-board vehicle control and data systems will warn drivers to stay alert or automatically summon tow or rescue services. Traffic advisories will be sent by cellular phone to on-board screens. In addition, on-the-fly electronic truck weigh-ins, electronic border clearance of cargo trucks, and electronic traffic management are just a few of the capabilities currently under development.

The issue of obsolescence cannot be addressed through high-performance "space-age" materials and structural durability alone. Stewards of the national infrastructure, including the private sector, must think outside the current and emergent technological envelopes. They must ask themselves not just what new modes/methods of transport are necessary or probable in the future, but also what new forms of transport will be ***possible*** in the next century. What types of infrastructure support will these exciting new conveyance systems require?

MAGNITUDE OF THE PROBLEM

The Physical Problem: Historical Under-Investment Has Led to Massive Decay, Deterioration, and Obsolescence

The well being and vitality of the transportation physical infrastructure are essential to the economic prosperity of the nation. Transport is a powerful economic engine, employing 12 million and attracting one of every 5 dollars in total household spending. In direct expenditures alone, transportation-related activities account for almost 20 percent of the U.S. Gross Domestic Product (GDP), with about 15 percent of that applied to construction, operation, and maintenance of transportation systems. Of these latter expenditures, more than 80 percent are for maintenance of our aging and deteriorating infrastructure. Dramatic improvements in transportation efficiency, productivity, and modal balance are essential to the nation's mobility, its national security, and its competitiveness in the global marketplace.

The resources invested in public works and infrastructure over the past decade fell far short of actual needs despite the dire warnings from experts that continued neglect and deterioration of our aging infrastructure would seriously undermine the national economy and our quality of life. Investments in the advancement of American civil infrastructure and its renewal are alarmingly low relative to other developed economies and downright paltry for the most powerful and prosperous nation in the world. Spending levels for infrastructure in 1997 are estimated to have been approximately $115.1 billion, including public investments of $78.8 billion (highways, sewer systems, water supply facilities, military facilities, conservation and development, power generation facilities, transit, airfields) and private investment of $36.3 billion (telecommunications, railroads, light and power, gas, petroleum pipelines). Moreover, according to a CERF/NSF survey, private and public sector R&D supporting the development of better, cheaper, and faster infrastructure technologies and practices is less than 0.5 percent of the annual expenditure for new construction and renovation. This figure is far below the approximately 3.5 percent average investment in R&D of other mature U.S. industries.

A preliminary scan of readily available statistics reveals a rough order-of-magnitude figure for renewing and upgrading the American infrastructure. **The data suggest that comprehensive and effective renewal of the nation's basic surface transport infrastructure could come with a price tag of substantially more than $600 billion**. A preliminary breakdown of these data is tabulated below. Note that the total cost estimate in Table 1 would be substantially higher if data in the "Modest Improvement" column were complete.

Table 1: Investment Estimates for Surface Infrastructure Revitalization ($ Billions)

Infrastructure Components	Correct Serious Deficiencies	Maintain Current Repair Levels	Modest Improvement	TOTAL
Highways	$263		$94	$357
Bridges	$80		NA*	$80
Transit & Rail	$87		NA	$87
Air Transport	$30			
Port Facilities	$46			
TOTAL	**$600**			

* Data not readily available for analysis

A rough derivation of the figures in Table 1 is provided below for each component shown in the table.

Highways and Bridges

In stark contrast to the $97.3 billion total infrastructure expenditures in 1997, the Federal Highway Administration (FHWA) estimates that the cost of eliminating highway deficiencies *alone* would be $212 billion! The American Association of State Highway and Transportation Officials (AASHTO) pegs the estimate even higher. AASHTO experts report that more than $263 billion in new investment is required just for maintenance of current levels of repair and capacity and an additional $94 billion would buy only modest improvements (a $357 billion total). FHWA estimates over 30% of the 582,000 bridges in the U.S. are functionally obsolete or structurally deficient, or both. Between $72 billion and $80 billion in new investment is required to reverse the downward trend in bridge safety and serviceability. Roadways and bridges should be the highest priority for new investment among all modes because they are the most heavily used components of the transport system. Despite the number of individuals working at home, Americans travel nearly twice as much as they did 25 years ago, and the number of vehicles has grown by 60 percent over that same period. More than 9 out of 10 personal trips take place on our nation's roads and highways. The number of miles in the highway system, however, has grown only by 3 percent since 1973. In addition, commercial trucking is the lifeline of our economy. The cost of trucking goods rises 6.3 cents

per mile when road conditions decline from "good" to "fair." More than 60 percent of our principal highway miles are in fair, mediocre, or poor condition.

Public Transit & Railroads

The American Public Transit Association (APTA) notes that 30 percent of rail transit and maintenance yards are in poor condition, and intercity rail line abandonment and deterioration is a growing problem, particularly in the Midwest and Northeast. The focus of inner city rail has been expansion of the rapid transit rather than the renewal of older systems (the Department of Transportation (DOT) requested $666 million for new transit systems in 1996). An $87 billion investment ($8.7 billion per year) is required over the next decade to maintain current service, track structure, and track service worthiness. An additional $51.2 billion is required to implement planned service expansion.

Air Transport

Passenger volume is expected to increase 57 percent over the coming decade because the airline industry will become more of a global sector. The American Public Works Association (APWA) reports that if no new runways are added, the number of severely congested major airports will grow by 250 percent. Ten of the 22 most congested major hubs will suffer gridlock by 2004 or 2005 even if all runways and associated appurtenances now planned by the Federal Aviation Administration (FAA) are built. The FAA estimates that $30 billion will be required to bring existing airports up to current design standards and expand capacity to meet projected demand.

Port Facilities

By definition, all water access ports are intermodal. A major port typically has three modal components: (1) ship channel to ship berthing (2) berth/docks to storage/staging and (3) gate/perimeter to truck/rail modes. In the context of this paper, the term "port facilities" is confined to the basic infrastructure of the nation's maritime ports. Port facilities are critically important to long-term U.S. economic prosperity. The growth rate of U.S. international shipping interests far exceeds that of any segment of the transport sector. Ocean going trade represents 90 per cent of all U.S. international commerce by weight. By 2020, the total tonnage of maritime trade is expected to triple 1998 levels.

The enormous growth of the U.S. maritime port industry is driven by two factors. First, global trade by water is exploding. The huge secondary markets for cranes, hoists, other lading equipment and specialty storage equipment is an unmistakable indicator that innovation in port operations is a direct function of the burgeoning market in shipping. Second, there is intense pressure to modify port facilities to stay abreast of rapidly changing international ship technology.

In 1996, one third of the 144 U.S. ports responded to an AAPA Port Development Expenditure Survey. These 48 ports spent a total of $1.3 billion for new facilities and infrastructure. This is double the investment level from 1991-1993 (another indicator of global market pressures). According to the 1996 AAPA survey, terminal infrastructure expenditures plus dredging costs represented more than 30 per cent of this figure ($420 million). Modernization and "rehabilitation" costs accounted for $270 million in 1996, incurred mostly in the North Atlantic and South Pacific. Of this amount, 39 per cent went toward infrastructure modernization and dredging ($106 million). Infrastructure expenditures are expected to increase 4 per cent annually from 1997 to 2001 for the 48 respondent ports. Dredging-related expenditures are forecasted to decrease marginally during the same period. As a proportion of total investment in the 48 U.S. ports responding to the AAPA survey, basic infrastructure rehabilitation and channel maintenance costs 1997-2001 will total about $2.2 billion, a $0.54 billion per year average. If the remaining U.S. ports had responded to the 1996 AAPA survey, it is reasonable to conclude that the annual price tag would be more than triple this amount, or about $2 billion per year ($20 billion total over the next 10 years). This figure reflects only non-military port facilities. Naval ports and facilities could amount to an additional $20-25 billion, bringing the potential total to $40-46 billion.

Outdated materials, technologies, or practices cannot meet the infrastructure needs of the 21st century. Neither can the nation afford to make infrastructure improvements without taking advantage of life-cycle cost savings made possible by use of advanced materials and technologies and the associated long-term impacts on capital, operations, and maintenance budgets. In light of the enormous sums involved, it would be folly to continue to employ only conventional materials and traditional methods for infrastructure renewal when innovative alternatives are available or are on the horizon. **The next generation infrastructure must be put in place with materials and engineered systems that are stronger and more durable or the cycle of massive decay will be inevitably repeated in another half century.**

The Cultural Problem: Liability Concerns, Procurement Practices, And Fragmentation Discourage Innovation

The high cost of insurance, the multitude of regulations, and industry fragmentation are the primary factors that combine to discourage innovation under current procurement practices. There is a very real perception that innovation is risky. Such disincentives are impeding technological advances in transportation in the U.S. As a result, global competitors are quickly gaining a market advantage. Estimates are that the cost of the U.S. tort system as a percentage of GDP is more than triple than in other industrial countries. The trend has had a particularly powerful effect in the design and construction industry. A recent American Consulting Engineers Council (ACEC) survey found that private engineering design firms turned down 69 percent more work in 1996 than in 1995 because of concern over liability exposure ($80 million, nationwide). Another ACEC survey revealed that the threat of litigation caused 76 percent of the survey respondents to avoid innovative methods and materials.

Although the U.S. design and construction industry represents almost 13 percent of our GDP, it is highly fragmented, comprising over 1.2 million firms, 85 percent of which have fewer than ten employees. Moreover, a decayed infrastructure affects all sectors of the nation's economy, even those outside the realm of the design and construction industry. All have a vested interest in a revitalized infrastructure—large manufacturing companies, small innovators, construction firms, private corporations—who depend on the infrastructure to deliver goods and services and remain profitable. Yet historically there has not been a strong, visible constituency regularly and visibly articulating the need for a revitalized infrastructure. There is a pressing need to unite the public infrastructure sector and its stakeholders to provide a mechanism for revitalizing the infrastructure. This advance can only be achieved through developing non-traditional cost-shared technology partnerships and consortia among **all** infrastructure stakeholders.

The Institutional Problem: Conservative And Incremental Approaches To Renewal Have Led To Piecemeal And Ineffective Solutions

In spite of the fact that well over a dozen federal agencies have instituted programs that address some aspects of materials and methods research, no single program has fundamentally changed the way we plan, design, finance, and build the nation's basic transportation infrastructure, such as highways and bridges. These efforts have produced valuable, albeit partial solutions to an overwhelming problem. With literally thousands of bridges being built or renovated each year, the construction of a few dozen prototype demonstration projects with high-performance materials and innovative design has a negligible impact on infrastructure revitalization. If we continue down this same path, there will be few, if any, incentives for material suppliers to invest in new plants and processes to improve infrastructure technologies and products. Moreover, despite the fact that our nation's infrastructure has deteriorated greatly in recent years, there is as yet no clear national constituency for repair, maintenance, and renewal. The only way to ensure that innovation is widely adopted and accepted for both new construction and repair is to develop a coherent national strategy that embraces and expands that constituency. Since the U.S. federal, state, and municipal governments play a vital role in the design, construction, and maintenance of major infrastructure elements, the responsibility to use innovative technologies and products should devolve to them as a matter of high-level policy and standard operational procedures. Yet the private sector must recognize this historic need and opportunity and help to fashion new ways to leverage private and public resources to repair and upgrade the infrastructure.

BUILDING THE PARTNERSHIP

The Partnership must combine private and public resources and serve both private and public interests. Building the Partnership will involve setting clear objectives and devising programs to meet those objectives without attempting to take on the work that others are doing.

Strategic Goals and Principal Objectives

PAIR-T will likely take an incremental approach to program implementation in the conviction that the initiative is so broad in scope and constituency that flexibility must be built in to accommodate changing priorities and foster realistic expectations. Therefore, near-, mid-, and long-term goals and objectives are planned. **PAIR-T must be a committed and synergistic collaboration among all stakeholders** to develop new technologies and products and accelerate market acceptance of innovative existing technologies. Stakeholder roles and responsibilities for achieving stated goals and objectives will become clearer as this plan is refined. Goals and objectives are presented below.

Near-Term Goals and Objectives (1998-2002)

Near-term activities will be directed to program definition and implementation and technology demonstration. Measures of program performance, or "metrics," must be defined quickly. A number of organizational mechanisms and vehicles must be put in place to facilitate program implementation. Significant effort will be devoted to building and demonstrating innovative urban intermodal infrastructure technologies on a wider scale and in a more systematic manner than ever before. Suggested near-term tasks are listed below:

- Develop a consensus on fundamental PAIR-T goals and objectives
- Establish performance criteria and realistic metrics to measure program achievement
- Develop a major educational and fund-raising campaign to gain widespread public support for the PAIR-T initiative
- Develop the "big picture" for a truly sustainable surface transport infrastructure, addressing both renewal and infrastructure obsolescence
- Develop a concept paper and cost-sharing scenarios for a multi-modal infrastructure strategy for the next millenium
- Employ the "virtual innovation center" concept to facilitate deployment of market-ready technologies, materials, and methods
- Implement innovative urban intermodal demonstrations and prepare a benefits assessment (using the "Lead State" concept)
- Develop and demonstrate "disaster-resistant" infrastructure systems and accelerate the construction of disaster-resistant communities
- Disseminate educational materials through outreach programs of the Transportation Research Board (TRB), APWA, Rebuild America Coalition, CERF, and other appropriate organizations
- Streamline the processes of identification, evaluation, and introduction of advanced high-performance systems, technologies, materials, and practices to regenerate civil infrastructure and continually advance the state of the art
- Accelerate the procurement and deployment of innovative technologies by state and local public works agencies *and* the private sector
- Define and break down institutional and financial barriers to the main stream adoption and acceptance of innovation in infrastructure renewal

In addition, an aggressive research program should be pursued to demonstrate capabilities that could achieve the milestones as identified under mid-term goals and objectives.

Mid-Term Goals and Objectives (2003-2008):

Achieving specific measurable program performance milestones against broad goals in key areas of concern is essential. *One of the key near-term technical tasks will be to establish realistic metrics to achieve improvements in operational capability in the mid-term. Preliminary mid-term metrics are proposed below as "strawmen" only.* (They were derived from the results of a 1994 workshop of the construction industry and the Construction and Building Subcommittee of the National Science and Technology Council).

- Extend the service life of existing infrastructure by 25 percent through renewal
- Increase the durability and reliability of infrastructure materials by 50 percent
- Reduce the perceived risks associated with innovation by improving worker safety (physical risk) and insurance (financial risk) at construction sites by 25 percent
- Enhance infrastructure performance to approach 95 percent system availability
- Expand the development and use of non-destructive testing (NDT) for bridge and road condition assessment by 30 percent
- Reduce the cost of infrastructure construction, operation, and maintenance by 25 percent
- Reduce the costs of infrastructure construction, operation, and maintenance by 25 percent
- Use at least 25 percent engineered, recycled alternative materials
- Reduce waste and pollution in construction by 50 percent
- Double federal funding for R&D on critical infrastructure protection

In addition, an aggressive research program should be pursued to demonstrate capabilities that could *double* the percentages of gains as listed above.

Long-Term Goals and Objectives (2008 and beyond):

As the "Vision" statement for this initiative contends, the ultimate goal of PAIR-T is to **accelerate the comprehensive renewal *and advancement*** of the aging civil transport infrastructure, moving toward the installation of a self-sustaining system. Theoretically, this ultimate "sustainable" system will be so maintenance-free, durable, and efficient that fewer and fewer human, economic, and environmental resources will be required to operate and maintain it. In a more pragmatic future, however, the reality is likely to be somewhat less grand. PAIR-T may be simply the way to free more resources so that a greater part of the transport infrastructure that is wanting may be rebuilt or replaced at a faster pace than would otherwise be possible

In terms of metrics, the principal long-term objective is to field operational capabilities that would more than double the percentages of the gains achieved in the mid-term. Ultimately, however, the successes of PAIR-T will be judged by succeeding generations against four major criteria: First, did PAIR-T contribute to day-to-day benefits for the traveling public and the private sector? Second, to what extent did work performed under the PAIR umbrella conserve the resources of the city, state, and local governments responsible for improving and maintaining the public infrastructure? Third, to what degree was PAIR-T successful in bringing together discrete and distinct private and public sector programs to achieve a common end in a cost-effective manner? Fourth, how effective was PAIR-T in educating taxpayers about the national security, impact of global change, environmental stewardship, and performance efficiency benefits that accrue to the public through innovation in infrastructure renewal

Investment Strategy

Financial sources and level of support anticipated for PAIR-T are discussed below. Clearly, the magnitude of the problem and the scope of the solution proposed herein suggest that resources from all sectors of the economy be brought to bear in a way that has never occurred before.

Minimum Annual Investment Levels Required

As discussed above, the investment required to bring the nation's surface transportation infrastructure into the next century could be more than $600 billion. PAIR strategists have estimated that an R&D investment of one-tenth of one percent of this amount over 10 years ($60 million per year) will significantly encourage and nurture real collaboration among the nation's civil infrastructure stakeholders. The level of funding is in addition to some of the critical revitalization programs already in place. The funding level should create sufficient momentum to create a sense of national priority and national constituency for PAIR-T and produce enough tangible benefits that PAIR-T will begin to be self-sustaining.

PAIR strategists project the overall return on investment in infrastructure renewal is more than enough to justify the expenditures proposed in this plan. It is estimated that the direct return on investment in infrastructure renewal of $60 million a year will be close to 300 percent, or $1.8 billion over the next decade. This projection does not even account for the estimated $50 billion a year in lost wages and wasted fuel caused by inadequate roads that can be saved. The U.S. DOT calculates that every dollar invested in the nations highway system alone will yield $2.60 in benefits to the economy.

As the principal custodians of the nation's civil infrastructure, government at all levels should lead the movement to restore this vital national resource. The concept of a government-led PAIR-T initiative, however, has always been predicated on leveraging funds from the private sector. There is no question that the success of PAIR generally, and PAIR-T specifically, will depend on the enthusiastic support and long-term commitment of the private sector. While governments and public institutions may plant the seeds for an effective infrastructure renewal program, only the active participation of representatives from *every* sector of the economy will result in real technological innovation. Furthermore, the Partnership harbors no illusions about the availability of government funds. National budgetary realities suggest that it is unrealistic to expect a major infusion of new, additional federal and state dollars to support PAIR-T. While additional federal and state funds would be welcome, the widespread involvement of the private sector, leveraging scarce national, public resources as effectively as possible, is at least equally important. Many private firms have yet to fully take advantage of some of current national R&D programs and public-private partnerships already in operation. The Partnership will work to build public awareness of resources currently available as well as to create new, additional public and private sector mechanisms to distribute the financial and intellectual burdens. **Corporate and other private sector in-kind and financial support is absolutely necessary if PAIR-T is to have a credible effect on promoting infrastructure revitalization.**

Anticipated Funding Sources

A suggested funding plan by source (cash and in-kind services combined) is summarized in the Table 2. Therefore, a major educational and fund-raising campaign should be instituted as part of an overall PAIR-T strategy.

As discussed earlier, many current and planned government programs support the R&D, evaluation, and development objectives of PAIR-T. It is anticipated that these program funds will be augmented by a *new* combination of leveraged private and public sector support, both direct and in-kind. The Partnership envisions involving the broadest possible range of infrastructure stakeholders, both in the identification of needs and the sharing of funding burdens. PAIR should generate significant leveraged funds from the private sector. Anticipated levels of initial financial support are shown in Table 2. Funding from states and transit authorities provided under the Highway Trust Fund may complement federal funds from the Department of Transportation (DOT), the National Science Foundation (NSF), the National Institute of Science and Technology (NIST), and the U.S. Army Corps of Engineers (USACE) and other federal agencies committed to the revitalization of our nation's infrastructure. In particular, the National Cooperative Highway Research Program (NCHRP), which identifies projects of regional and national significance and is administered by TRB and AASHTO, is a promising source of partnership and collaborative funding. A new mechanism is the FHWA's pilot State Infrastructure Banks program, which is demonstrating innovative financing mechanisms for infrastructure projects.

Table 2: Suggested Funding Plan

($ Millions)

	ANNUAL NEAR-TERM (1998-2002)	ANNUAL MID-TERM (2003-2008)	ANNUAL LONG-TERM (> 2008)
GOVERNMENT	$7	$12 – 23	$23 +
PRIVATE	$3	$21 – 33	$33 +
OTHER	$0	$ 2 – 4	$4 +
Total Yearly	$10	$35 – 60	$60+

Bearing in mind that PAIR-T is intended to be a coordinated effort on an unprecedented scale, additional funding, particularly on a matching basis, is potentially available from still other sources. **The forthcoming reauthorization of ISTEA can serve as a major initial catalyst for this effort.** Others include DOT grants to University Transportation Centers and University Research Institutes; the FAA's Airport Improvement Program; the U.S. Maritime Administration (MARAD); the U.S. Coast Guard (USCG), and Navy funding for port and inter-modal facilities; the Department of Defense (DoD) (Air Force, Navy, USACE); and trade and industry associations.

PAIR-T Participants

As indicated in the "Partnership Vision" statement, PAIR-T was conceived as an inclusive program. All stakeholders must accept the concept and commit resources to its development and implementation. Individuals and organizations from all sectors of the economy will be invited to participate. A partial list of key stakeholders is provided below.

Federal & Other Government Participants

- ***Key Financial Resource Base and Principal Developers and the Primary Custodians of the Civil Infrastructure:*** State and local highway and transit agencies, airports, and port authorities; DOT [FHWA, Research and Special Programs Administration (RSPA), Federal Railroad Administration (FRA), Federal Transit Administration (FTA), FAA, USCG], DoD (USACE), DOC/NIST, MARAD, and NSF

Other Participants:

Private Sector

- ***The Primary Technological & Financial Resource and Custodians of Privately-Owned Infrastructure:*** Major corporations in specific industries such as chemical, automotive, materiel manufacturers, commercial freight, construction, petroleum, air transport, construction equipment makers, insurance, information technology, and consumer products; infrastructure planning and management consultants, designers, and constructors

- ***Communications, Water, Waste Water, Gas, and Electric Utilities***

Not-for-Profit Foundations & Associations:

- ***The Lead Facilitator and Technical Coordinator:*** CERF/ASCE, its Innovation Centers, and allied CERF research programs

- ***Industry & Trade Associations: The Policy-Level Voice of Non-Governmental Organizations***: The American Automobile Association (AAA), AAPA, American Automobile Manufacturers Association (AAMA), AASHTO, American Chemical Manufacturers Association (ACMA), American Road & Transportation Builders Association (ARTBA), APTA, APWA, Association of American Railroads (AAR), the American Trucking Associations Inc. (ATA), ITS America, the Rebuild America Coalition, the Surface Transportation Policy Project, TRB, and many other organizations
- ***Universities and Colleges***

Partnership Management and Resources

PAIR-T is a critical element of the PAIR program and thus will be closely coordinated with PAIR activities. PAIR, and obviously PAIR-T and other core elements as well, is explicitly a partnership between the private and public sectors. Funding commitments are essential from both the private sector and from the key federal, state and local public owners of highways, bridges, and other elements of our nation's surface infrastructure. Planning, monitoring, and coordination responsibilities for PAIR-T must be shared by these two groups as well. Without shared public and private funding the PAIR-T initiative will lack credibility, but without shared management responsibility, there will be no effective accountability.

PAIR does not envision or wish to create a "new" program or entity to supercede existing public or private sector programs. PAIR will not fund or manage collaborative research programs. Rather, PAIR will promote and encourage collaborative research efforts and the effective leveraging of limited resources. Its success will ultimately be measured by the acceleration of innovation in products and services as developed by a growing variety and scope of private-public partnerships. We estimate that these partnerships could invest as much as $1 billion per year in research, development, and deployment, a doubling of current investment commitments.

The President established the National Science and Technology Council (NSTC), a cabinet-level group charged with setting Federal science and technology policy, to coordinate and prioritize R&D and deployment strategies across a broad cross-section of public and private interests. It recently reorganized its committee structure into four research and development committees, including the Committee on Technology. Under the Committee on Technology the Subcommittee on Construction and Building coordinates and defines priorities for Federal research, development and deployment related to the industries that produce, operate and maintain constructed facilities, including buildings and infrastructure. Fourteen Federal agencies are represented on the Subcommittee.

The Subcommittee is involved in partnerships with industry and academia such as PAIR to accomplish its goals through research, development, and application of innovative products and practices. For example, the Subcommittee is supporting a project being performed by the National Conference of States on Building Codes and Standards (NCSBCS), and the Partnership for Advancing Technology in Housing (PATH) to streamline the building regulatory process.

PAIR's organizational structure and goals are illustrated in the figure on the following page. PAIR-T activities will be coordinated through this structure. It is envisioned that an all-volunteer PAIR Executive Committee (PAIR ExCom) will be established by the principal segments of the stakeholder community: government, industry, associations and foundations, and academic institutions. ExCom members may be nominated by any of the Partnership's participants and elected by the Partnership as a whole. The NSTC Subcommittee on Construction and Building, which is composed of representatives of 14 federal agencies, will be represented on the Executive Committee. The ExCom will be responsible for development and administration of PAIR's operating policies, including its fiscal and administrative procedures. The ExCom will also provide guidance on all major PAIR initiatives, such as the development of infrastructure-performance metrics, research agendas, and educational and fund-raising campaigns.

CERF as Partnership Secretariat

The Civil Engineering Research Foundation (CERF) will serve as Secretariat to the PAIR Excom. In this role, CERF will facilitate, integrate, and collaborate with all partnership members. CERF will, for example, be responsible for convening the Committee's meetings, disseminating information about PAIR to the general public, coordinating the day-to-day activities of PAIR's initiatives, and other administrative tasks as assigned by the Executive Committee. As PAIR's Secretariat, CERF will facilitate collaboration and coordination among the Partnership's members, but the real direction of PAIP will come from industry and state and local government: these participants are the technology buyers and the stewards and beneficiaries of the nation's infrastructure. The estimated costs for the ExCom and Secretariat activities are estimated to be $1 million per year as PAIR gets fully underway. These operating costs are but one-tenth of one percent of the amount of projected RD&D collaborative activities that are expected from the new focus developed through PAIR.

CERF was established in 1989 by the American Society of Civil Engineers (ASCE) as an independent 501(c)(3) nonprofit organization, to coordinate research and innovation for the design and construction industry. CERF brings together suppliers and consumers, academics and practitioners, owners and users to facilitate the transfer of information and technology into practice. CERF's sole agenda is encouraging the rapid commercialization and integration of new technology and practices of benefit to the design and construction communities. CERF currently serves as the Secretariat or focal point for a number of national programs to accelerate advanced materials use and promote innovative technologies.

CERF is well known for its Innovation Centers, which it operates in the areas of highways, infrastructure, buildings, and the environment. The Highway Technology Evaluation Center (HITEC), developed in partnership with the Federal Highway Administration, is a nationally recognized service center and clearinghouse for implementing highway innovation, evaluating products, materials, services, equipment, and systems such as composite bridge decks, earth retaining systems, and heated pavement systems. The Environmental Technology Evaluation Center (EvTEC), established through a cooperative agreement with the U.S. Environmental Protection Agency (EPA), is designed to promote the acceptance of innovative environmental management technologies. The Civil Engineering Innovative Technology Evaluation Center (CEITEC) provides performance evaluations services for a wide spectrum of innovative technologies, with particular emphasis on public works, military applications, and trenchless technologies. In collaboration between CERF and the National Evaluation Service (NES), NES-BIC serves the building and residential housing industries. NES-BIC was formed through a partnership of industry and government stakeholders who recognized the need for an effective, expedited means to bring building innovation to the marketplace. The Center provides an independent technical evaluation service for building technologies for all types and can be used by innovators, designers, or those who own and operate facilities to gain credible information on the performance of new technology.

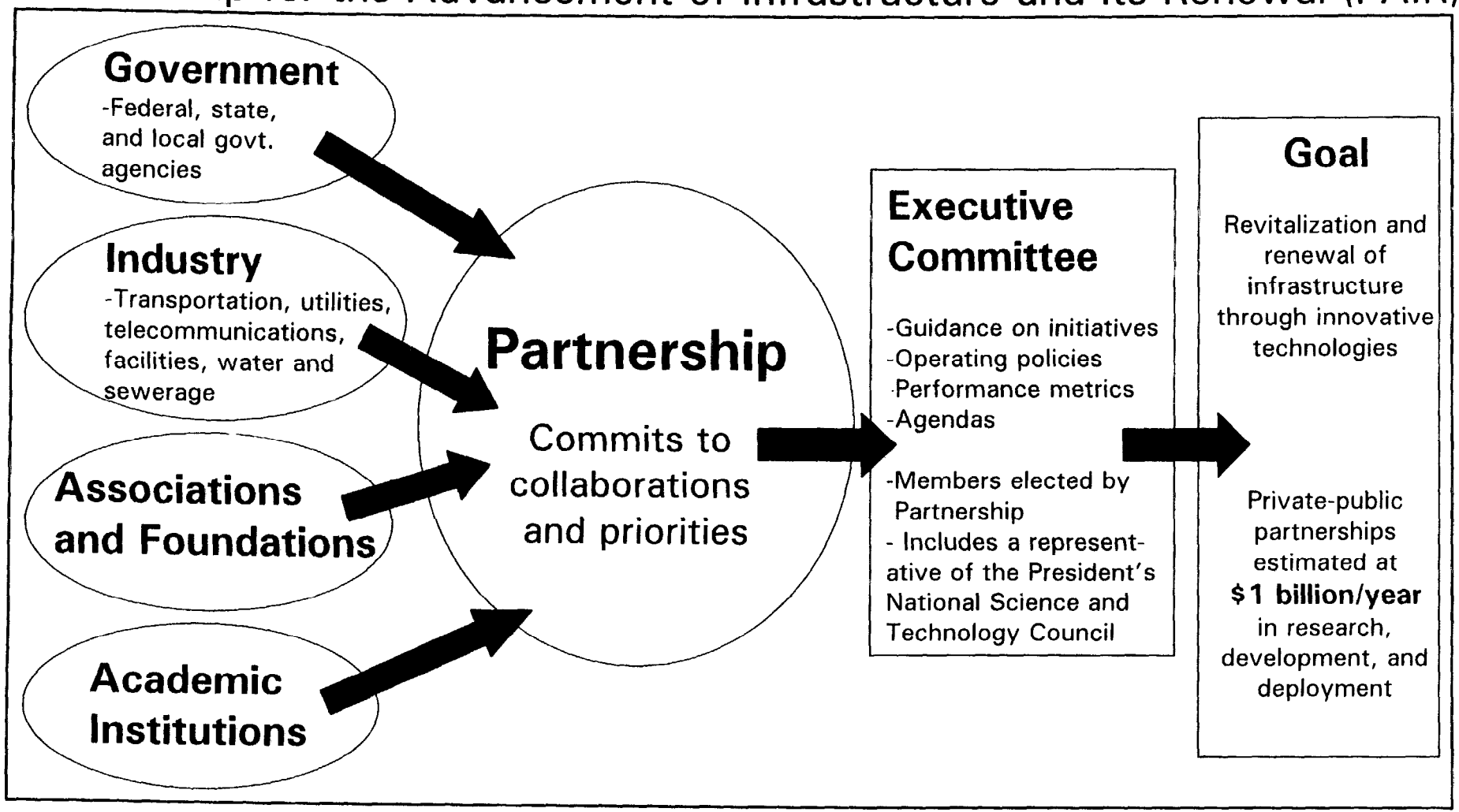
With all of the Innovation Centers, evaluations are planned, conducted, and overseen by panels of technical experts who represent the entire stakeholder community of potential users or purchasers of the products or technologies.

In addition to the Innovation Centers, CERF serves as Secretariat for the high-performance CONstruction MATerials and systems program (CONMAT). CONMAT is a cooperative industry-government partnership that works closely with universities to accelerate the commercialization of innovative construction materials and systems for the erection, repair, and retrofit of structures.

CERF has no agenda other than the most rapid commercialization and integration of new technology and practices of benefit to the design and construction communities. It serves as an unbiased and uncompromising champion of infrastructure renewal, consciously involving all construction sectors in its mission. CERF currently serves as the Secretariat or focal point for a wide range of national programs accelerating advanced materials use and promoting innovative technologies.

Fig. 1: Building the Partnership

Partnership for the Advancement of Infrastructure and Its Renewal (PAIR)



SECRETARIAT: CERF

Facilitate and coordinate, disseminate information, administration

Estimated operating costs for Executive Committee and Secretariat: ***$1 million/year***

CERF is ideally positioned to assist government and industry in coming together for the formulation and implementation of a unified and integrated set of national programs to which all stakeholders may comfortably commit.

TAKING THE FIRST STEPS

One of the early tasks now facing the Partnership will be to initiate modest educational and fund-raising campaigns within the private sector to complement public funds already earmarked for PAIR secretariat activities. Many current and planned government programs have objectives compatible to PAIR's, and these programs may be sources of seed funds for the Partnership. Combinations of new leveraged private and public sector support, both direct and in-kind, will then be the means for the growth of PAIR's initiatives.

Existing Complementary Programs

PAIR-T builds on earlier public-private partnerships. For example, HITEC, CERF's nationally recognized service center and clearinghouse for implementing highway innovation, was funded in part by FHWA under ISTEA. The recently authorized Transportation Equity Act for the 21st Century (TEA-21) may be an effective vehicle for some of the objectives of PAIR-T. Similarly, the CONMAT program is explicitly based on developing partnerships between and among the public and private sectors. The Rebuild America Coalition as well has brought together individuals and organizations from a very broad cross-section of the nation.

Existing and planned federal research and technology transfer programs reflect the traditional needs and responsibilities of the agencies that support them. For instance, DOT's research programs largely support the Department's safety missions or its operational responsibilities, with less emphasis on the needs related to infrastructure monitoring, maintenance, and renewal. A key effort is the National Technology Deployment Initiative (NTDI). Moreover, the Department also disburses large block grants to states, engages in a number of cooperative research programs, and maintains a large network of University Transportation Centers and University Research Institutes. Over the past three years, in particular, the National Science and Technology Council's Construction and Building Subcommittee, with active DOT participation, led a number of workshops and published white papers. One notable paper was entitled "Innovation in the U.S. Construction Industry: An Essential Component for America's Prosperity and Well Being." Published brochures include "Federal R&D in Support of the U.S. Construction Industry," which developed the vision and national goals for a broad government-industry partnership in construction.

The 1996 International Symposium on Engineering and Construction for Sustainable Development established blueprints for accelerating innovation and applied research and demonstration in engineering and construction. Key documents included *Creating the 21st Century through Innovation* and *Construction Industry Research Prospectuses for the 21st Century.* The CONMAT program has produced a number of publications outlining strategies to utilize high-performance construction materials in reviving our nation's infrastructure, most notably in *Materials for Tomorrow's Infrastructure: A Ten-Year Plan for Deploying High-Performance Construction Materials and Systems*. Both of these efforts focus heavily on the transportation infrastructure. The PAIR-T proposal builds on these earlier efforts. Other important initiatives are focused on the following topics:

- Advanced construction materials
- Highway pavements
- Highway structures
- Safety
- Computer modeling and simulation
- Fire safety at airports
- Terminal security at airports
- Airport pavements
- Rail infrastructure safety
- Non-destructive assessment methods
- Accessibility for the disabled
- Pipeline safety, durability, and failure detection
- Rail infrastructure vulnerability to disaster

- Emergency response planning
- Deterioration science
- "Smart" materials and sensing devices
- Renewal engineering
- Disaster mitigation technologies
- Planning methods and tools
- Inter-modal facilities design
- Software applications for planning and maintenance

Planned Initiatives

To achieve stated PAIR-T goals and objectives, the Committee will help coordinate a number of initiatives in four major areas. These efforts will address cross-cutting (intermodal) issues in the transport infrastructure community, thereby reinforcing PAIR-T relevance and the notion that real benefits will accrue to those who are active in this new paradigm of "unprecedented collaboration":

TECHNOLOGY R&D INITIATIVES

- Deterioration science
- Embedded and mobile NDT
- Cost-effective infrastructure manufacturing and construction
- Information technology to collect, analyze, and model data infrastructure condition and performance
- Streamlining construction site operations
- Advanced materials (CONMAT)
- Rapid disaster response and recovery
- Planning and engineering methods (including life-cycle costing)
- Engineered infrastructure systems, subsystems, and components
- Quality Control and Quality Assurance

ASSESSMENT INITIATIVES

- Infrastructure sustainability
- Infrastructure obsolescence
- Multi-modal infrastructure technology strategies
- Novel future technologies
- Performance criteria and metrics
- Repair, renewal, and replacement needs
- Risk-transfer and risk mitigation
- Performance specifications

DEMONSTRATION, EVALUATION AND DEPLOYMENT

- Site selection and management
- Virtual Incubation Center
- Data and information

EDUCATION & OUTREACH INITIATIVES

- Biennial conference
- Publications
- NSF Institute for Civil Infrastructure Systems (ICIS)
- National recognition program for states and local governments
- Infrastructure innovation benefits

Funding

As discussed in the "Investment Strategy" portion of this plan, a total of $60 million per fiscal year is suggested for R&D, technology demonstration programs, and the other activities described in this plan. The specific cost-share goals of each member of the Partnership have not been determined at this time. The key budgetary uncertainties are reauthorization of ISTEA and enlisting support for the long term Partnership-wide cost-sharing commitments required for technology R&D, demonstration, and deployment.

Major Issues and Challenges

The key challenge is developing a stable source of funding for PAIR-T. As indicated above, the PAIR-T concept has always been predicated on the identification and procurement of matching funds from the private sector. Therefore, a major educational and fund-raising campaign must be instituted early on in the PAIR-T effort. Overcoming government budgetary constraints is also a significant challenge and will require a concerted effort by government officials and institutions such as CERF/ASCE who want to champion the PAIR-T cause to Congress and the Administration.

As discussed in the opening sections of this plan, there are cultural and institutional barriers to overcome. The infrastructure sector is highly fragmented, which makes taking action on a united front difficult. In addition, the public works and civil infrastructure community is historically conservative and risk-averse. Only if "market pull" matches the "technology push" can innovations rapidly and routinely penetrate and be accepted in the marketplace. PAIR-T is now only a dream. Its realization will demand the best from those who stand to gain the most from turning the dream into reality.

ACRONYMS AND ABBREVIATIONS

AAA	American Automobile Association
AAMA	American Automobile Manufacturers Association
AAPA	American Association of Port Authorities
AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACEC	American Consulting Engineers Council
ACMA	American Chemical Manufacturers Association
AISI	American Iron and Steel Institute
APTA	American Public Transit Association
APWA	American Public Works Association
ARTBA	American Road & Transportation Builders Association
ASCE	American Society of Civil Engineers
ATA	American Trucking Associations, Inc.
CEITEC	Construction/Civil Engineering Innovative Technology Evaluation Center
CERF	Civil Engineering Research Foundation (the research affiliate of ASCE)
CONMAT	High-Performance CONstruction MATerials and Systems program
DoD	Department of Defense

DOT	Department of Transportation
EvTEC	Environmental Technology Evaluation Center
FAA	Federal Aviation Administration, Department of Transportation
FHWA	Federal Highway Administration, Department of Transportation
FRA	Federal Railroad Administration, Department of Transportation
FRP	fiber reinforced polymers
FTA	Federal Transit Administration, Department of Transportation
GDP	gross domestic product
HITEC	Highway Innovative Technology Evaluation Center
HUD	Department of Housing and Urban Development
ICIS	Institute for Civil Infrastructure Systems
ISTEA	Intermodal Surface Transportation Efficiency Act
ITS	intelligent transportation systems
MARAD	Maritime Administration, Department of Transportation
MPa	Mega-Pascals
NCHRP	National Cooperative Highway Research Program
NDT	non-destructive testing
NES-BIC	National Evaluation Service-Building Innovation Center
NIST	National Institute of Standards and Technology
NTDI	National Technology Deployment Initiative
NSF	National Science Foundation
PAIR	Partnership for the Advancement of Infrastructure and its Renewal
PAIR-T	Partnership for the Advancement of Infrastructure and its Renewal – Transportation
PATH	Partnership for Advancing Technologies in Housing
PCCIP	President's Commission on Critical Infrastructure Protection
R&D	research and development
RSPA	Research and Special Programs Administration
SMAs	shape memory alloys
TEA-21	Transportation Equity Act for the 21st Century
TRB	Transportation Research Board
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard